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The Parameters of the Process of Dry Cleaning Root Crops with Using Screw Separator.

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ABSTRACT

Engineered a constructive flow chart of cleaner of root crops. Theoretical and experimental studies of the cleaning process of root crops. Substantiates the basic structural and operational parameters of the proposed cleaner.
Keywords: root crops, analysis, the separating-purifying working bodies

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INTRODUCTION

In the process of production and preparation of feed occupies an important place to use different feed mixes with the use as a component of fodder root crops. Root vegetables - tasty, good food eaten by animals. This feed significantly improve livestock rations during the winter. Especially valuable root for dairy cattle and calves, tubers - for pigs. According to the composition and nutritional melon roots and a high content of physiologically bound water (from 70 to 90% or more) and small amounts of fat and fiber. The protein content is also low (1-2%), with about half of its amount to amides. Protein root vegetable is rich in the amino acids lysine and tryptophan. The dry substance of roots represented by carbohydrates sucrose, starch, pectin and hemicellulose. The roots poor by calcium and phosphorous (0.03-0.04%), contains more potassium than sodium. Carrots are rich in vitamin C (ascorbic acid), some species are a good source of carotene. Digested nutrients root crops by 85-90% [12].

Sugar beet is a good food for all kinds of farm animals. For dairy cows, it is lactiferous forage. Cattle fed raw sugar beet in the form of cuts, up to 20-25 kg for adults and up to 15 kg per day for the young [1, 13].

Pigs are also willing to eat beets raw, but it is better to feed cooked - up to 6-8 kg per day per 100 kg of live weight.

One of the main operations in the preparation of root crops for feeding a cleaning them from the soil. Contamination of root crops, which is in the range 7-28%, can be classified into groups: heavy impurities (stones, pieces of metal, etc.) adhering soil and light impurities (straw, plant residues) [11, 14].

The solution to this problem to achieve substantial savings. This can be achieved by improving the existing machines or create new ones. In this regard, there is need for a new efficient device with broad technological capabilities.

MATERIALS AND METHODS

Analysis of flow production lines allow to show that the funds dry cleaning root crops are the most promising.

The complexity of the root-crops cleaning creates a real need to study processes occurring in cleaner roots, with the help of mathematical models.

In this regard, the most interest from the standpoint of cost reduction and improvement of quality indicators of cleaning root crops, is an apparatus for cleaning root crops from impurities (RF patent № 23997633) [5, 10].

A theoretical study of the design features of the cleaner. The basis of the separation of lumps of soil from root crops with the help of the working body of the screw separator The principle of sequential destruction of lumps in their simultaneous translation and rotation (around its axis) motion.

In operation, the lumps of soil and roots move along elongated cycloid - trochoid that provides the rotation of the screws with different angular velocity [2, 9].

To ensure the normal operation of the device is necessary to satisfy the following condition [3, 8, 16]:

$$\lambda = \frac{\omega_2}{\omega_1} > 1, \quad (1)$$

where λ – measure the kinematic mode; ω_2 – the angular velocity of rotation of the high-speed screw, s^{-1}; ω_1 – the angular speed of rotation of the low speed screw, s^{-1};

Bandwidth cleaner defined in the general form:

$$V = \omega t \varphi_{зап} (F_к \cdot \rho_к + F_п \cdot \rho_п)\ , \quad (2)$$

where $F_к$– cross-sectional area of root, m^2 ; $F_п$– cross-sectional area of impurities, m^2; $\rho_к$– the average density of root crops, kg/m^3 ; $\rho_п$– the average density of impurities, kg/m^3 ; ω – speed lumps and root axially, s^{-1}; t – step screw winding, m; φ_{spare}- fill factor workspace φ_{spare}=0,9.

The radius defined by side augers dimensional characteristics of root crops and, in particular, the length of root crops:

$$R = \frac{\sum_{i=1}^{n} l_i m_i}{\sum_{i=1}^{n} m_i} \cos \alpha_{\text{cp}}, \quad (3)$$

where n – number of fractions; l – length of root crops in each of the fractions, m; m_i– the mass of each fraction of root crops.

In this case, the cross-sectional area of the working space of the working body is equal to:

$$F_к = \frac{1}{2}\left(B_{\text{cp}} + \Delta S\right)\left(\frac{\sum_{i-1}^{n} l_i mq}{\sum_{i-1}^{n} mq}\right). \quad (4)$$

The main parameters of screw diameter is D_s, step helix t, height of turns and the gap between adjacent screws. With increasing diameter and increasing the clearance between the auger screw gripping ability. These options must be chosen from the condition of pulling impurities and lack of root vegetables pinch (Figure 1)

Figure 1

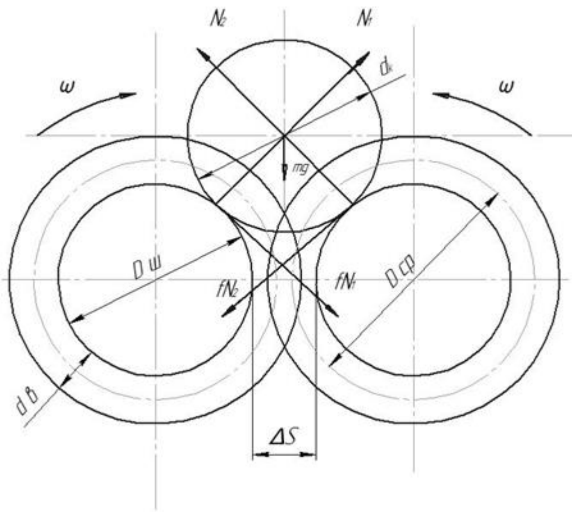

Figure 1: Schematic of the interaction with the screw root c

$$\frac{d_k \cos \varphi_k - \Delta S}{1 - \cos \varphi_k} > D_s > \frac{d_n \cos \varphi_n - \Delta S}{1 - \cos \varphi_n}, \quad (5)$$

where d_k иd_n – respectively, the diameter and thickness of root crops impurities (plant residues, soil lumps, etc.), mm; φ_k и φ_n – respectively, angle of friction on the surface of the screw root crops and separates impurities; ΔS– the gap between the screws, mm.

For effective separation gaps between adjacent soil augers must be large enough, but not more than the diameter of the fine roots.

Bandwidth cleaner can be determined by the expression:

$$Q = \frac{1}{2}\left(\text{B}_{\text{cp}} + S\right)\left(\frac{\sum_{i=1}^{n} l_i m_i}{\sum_{i=1}^{n} m_i}\right)\frac{\omega D_{\text{ш}}^2}{2t}\lambda\rho\varphi_{\text{зап}}, \quad (6)$$

where B_{cp} – the average width of root; S – the clearance between the screws, m; l_i– the length of the root of each fraction, kg; ω– frequency rotation of root, s^{-1};D_s – the diameter of the screw, m; t – step screw threads; ρ – the density of root crops, kg/m^3;

Net power, the need to drive cleaner, root crops consumed in the movement along the axis of the screw and to overcome the friction of the material of the screw coiling.

The capacity to move crops along the axis of the screw is defined:

$$N_1 = \frac{0{,}01R(Q + 40\pi R^2 L_{тр}\lambda\varphi_{зап}\rho)}{\eta} + N_0, \quad (7)$$

where Q – bandwidth sinks in t/h; R – the radius of the screw, m; ω– the angular velocity of the low speed screw, s^{-1};$L_{тр}$ – the length of the screw, m; λ– measure the kinematic mode; $\varphi_{зап}$– filling factor; ρ – bulk density of root crops, H; η – efficiency of the transmission (0,87).

RESULTS AND DISCUSSION

On the basis of theoretical studies show that a significant impact on the process of dry cleaning of root crops in the proposed screw-type cleaner following factors: measure the kinematic mode λ; the diameter of the screw D_s, ь; step screw winding l, m; the length of the working area clean root vegetables $L_{тр}$, m. To determine the effect of selected factors on the stability of the working process of the machine implemented a plan of full factorial experiment 2^3.

The criteria for optimization of the studied object selected: energy intensity - N (response Y_1), the bandwidth Q (response Y_2), separation efficiency (response Y_3)

The study was conducted in a pilot plant (Figure 2).

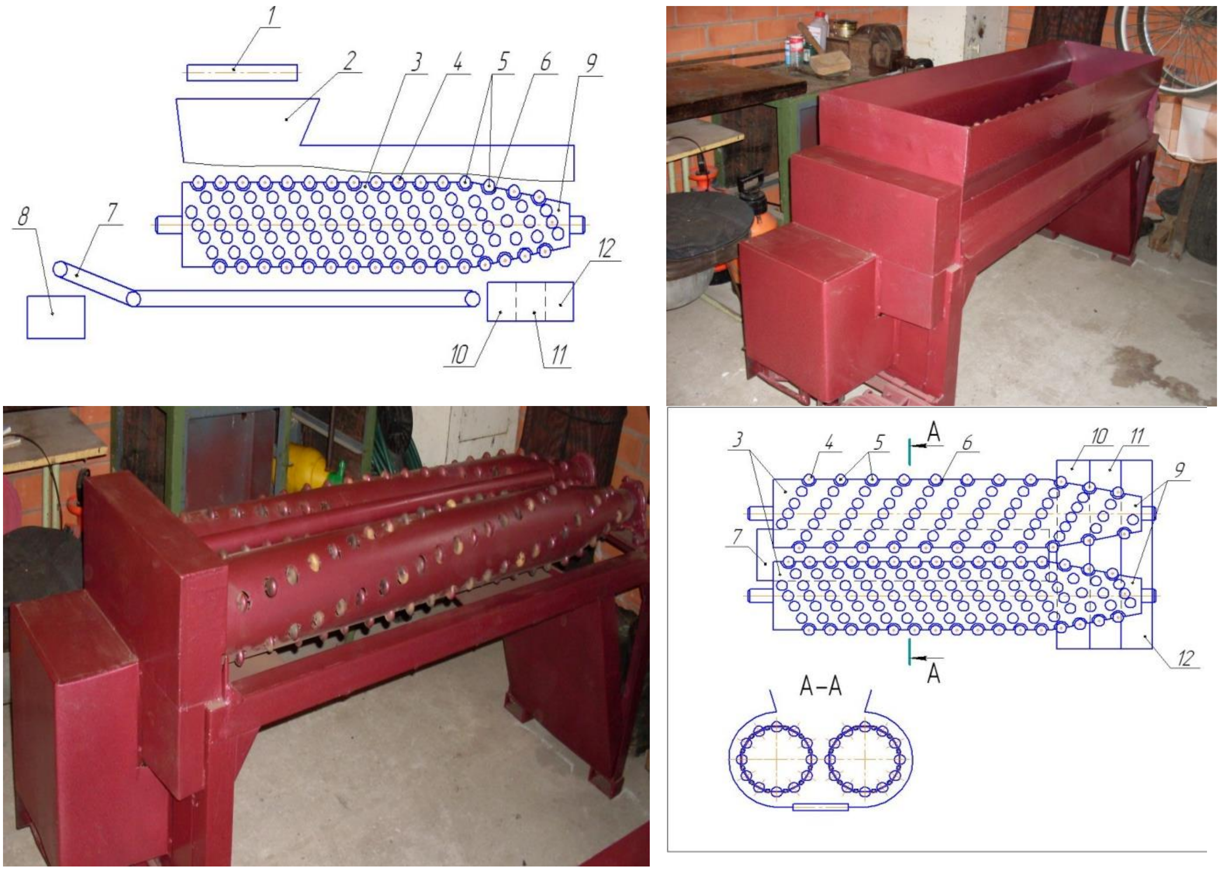

Figure 2: General view of the cleaner of root crops

After processing of the experimental results obtained adequate mathematical models, which have the form [4]:

– for energy consumption:

$$N=2265{,}634 + 266{,}7018\lambda - 40553{,}155D_ш - 1589{,}38l - 860{,}652L_{тр} + 7{,}5\,\lambda D_ш + 0{,}125\lambda L_{тр} + 12{,}5D_ш l - 0{,}625lL_{тр} - 59{,}1619\,\lambda^2 + 116857{,}62D_ш^{\,2} + 1149{,}5238l^2 + 290{,}2381L_{тр}^{\,2};$$

– for bandwidth:

$$Q= -10766{,}546 - 1032{,}7\lambda + 185133{,}33D_ш + 6254{,}88l + 3407{,}447L_{тр} + 13332{,}5\lambda D_ш + 3384{,}25\lambda l + 1590{,}875\lambda L_{тр} + 18287{,}5D_ш l + 9081{,}25D_ш L_{тр} + 2235{,}625lL_{тр} + 273{,}8190333\lambda^2 - 526883{,}33D_ш^{\,2} - 5230{,}714267l^2 - 1317{,}2024L_{тр}^{\,2}.$$

– for purity:

$$\xi=37{,}3621+12{,}6885\lambda +1137{,}996D_ш +9{,}5833l - 25L_{тр} - 25\lambda D_ш + 5\lambda l - 1{,}25\lambda L_{тр} - 250D_ш l - 62{,}5D_ш L_{тр} - 12{,}5lL_{тр} - 2{,}5714\lambda^2 - 2619{,}05D_ш^{\,2}+11{,}9048l^2 + 12{,}5L_{тр}^{\,2};$$

When optimizing factors (kinematic mode, screw diameter, screw pitch winding, the length of the work area), affecting the cleaning process of root crops used multicriteria evaluation method of rational factors. The criteria: capacity, bandwidth and quality of treatment. When optimizing the allocation principle used basic criteria of quality treatment, and the rest (throughput and capacity) as delimiters within a certain variation of the terms of the rational functioning of root crops shneokovogo cleaner separator. It uses known methods of nonlinear programming - a method of scanning with restrictions [5, 15].

restrictions:

$$N=64{,}42113+29{,}06X_1+3{,}1952X_2-9{,}06323X_3-9{,}20507X_4+0{,}0015X_1X_2+0{,}0005X_1X_3+0{,}0005X_1X_4-0{,}0002X_2X_3-0{,}0002X_2X_4-0{,}0013X_3X_4-0{,}2797X_1^2-0{,}02813X_2^2+0{,}0894X_3^2+0{,}090767X_4^2 \qquad 0{,}65 \le N \le 0{,}73$$

$$Q2434{,}09+1121{,}689367X_1+176{,}6892667X_2+372{,}133X_3-0{,}13977X_4+0{,}0071X_1X_2+0{,}0371X_1X_3+0{,}0341X_1X_4+0{,}0063X_2X_3++0{,}0063X_2X_4+0{,}0142X_3X_4-10{,}67536667X_1^2-1{,}677966667X_2^2-3{,}592833333X_3^2-3{,}3789X_4^2 \qquad 2400 \le Q \le 2500 \quad (A)$$

purification efficiency:

$$\xi= 0{,}9527+0{,}013267X_1+0{,}0115X_2+0{,}0071X_3+0{,}0053X_4-0{,}0001X_1^2 \qquad 0{,}95 \le \xi \le 0{,}96$$

We analyzed three criteria optimization (energy consumption, the degree of cleaning and bandwidth) as an extremum for a response surface constraints imposed by other surfaces of the response. In this regard, we solved the problem of finding a compromise between the optimization criteria.

Figure 3 shows the dependence of $Q=f(\lambda)$ the capacity of the root crop index cleaner kinematic mode. Analysis of the dependence $Q = f(\lambda)$ indicates that the capacity of the machine with an increase in kinematic mode is continuously increasing to a value of 2450- 2500 kg/h at λ = 2,1-2,2.

Then there is the actual reduction of capacity to the value Q = 2650 kg / h at λ = 2,5. This is because the reaction time hemispheres winding the root surface is reduced, whereby the latter "jumps" across the coil winding of the screw, and thus slows the movement in the axial direction of the screws. This in turn leads to a decrease in throughput and increase costs cardinality.

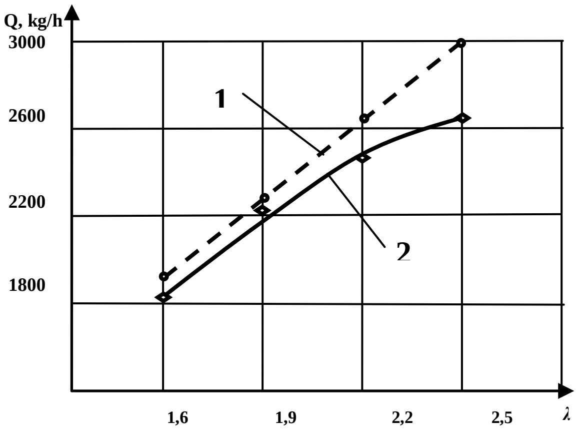

Figure 3: Dependence of capacity Q of the kinematic mode λ.
(1- calculated Q = f (λ), 2 - actual)

The analysis can be concluded that optimal constructive-regime parameters for cleaning of root crops comply with the following values:

– for the index kinematic mode λ= 2,2;
– for the diameter of the screws $D_ш$= 0,178 m;
– for step screw winding l = 0,68 m;
– for the length of the working zone clean $L_{тр}$= 1,5 m.
The values of the optimization criteria at the optimum combination of factors following:
– bandwidth Q of 2450 to 2500 kg / h;
– energy consumption N=0,62$\frac{(W \cdot h)}{kg}$;
– purification efficiency ξ=95,3 %.

CONCLUSION

Identified ways to improve the technological means for cleaning of root crops, which are based on the principle of sequential destruction of lumps in their simultaneous translation and rotation (around its axis) motion. The cleaning process is implemented cleaner screw-type wound in the form of hemispheres, providing high quality cleaning while reducing the consumption of energy and labor costs to perform the process (technical novelty confirmed patent for invention №2397633 of Russian Federation).

Dependency analysis showed that the process of dry cleaning root crops significantly affect: the kinematic mode indicator - λ; screw diameter - $D_ш$; step screw threads - t; screw length - $L_{тр}$; S - clearance between the screws, as well as physical and mechanical properties of root crops

An experimental installation of root crops cleaner screw type with working bodies, wrapped which is in the form of hemispheres, rotating on axes that allows you to change the kinematic mode indicator in the range of λ = 1,5-2,5 at a filling factor ϕzap = 0,5-0,9.

Implementation of the proposed conservation process of dry cleaning of root crops can reduce the metal content of 1,2 times, the unit cost of water – 0,1 l/kg.

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